Convection and Shear Flow in TC Development and Intensification

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LONG TERM GOALS

To study the dynamic processes of tropical cyclone (TC) development in the western North Pacific through field observational data and theoretical modeling.

OBJECTIVES

The objectives are: (1) to study the convection and vorticity generations in the vortex environment that may lead to the development and intensification of tropical cyclone; (2) to study the development and evolution of deep moist mesoscale convective system subject to strain effect due to the horizontal shear associated with the vortex rotation; (3) to study the offsetting between (1) and (2); (4) to study nonlinear interactions that may lead to additional strain effects that may impact on the convection in ways that are not yet known.

APPROACH

TCS-08 offers a unique opportunity to collect high resolution data of kinematic and thermodynamic fields to determine the filamentation time, which is a function of total deformations and vorticity. The NRL P-3 aircraft with ELDORA airborne radar made it possible to directly compute the filamentation time at the convection scale, allowing an investigation into the effect of filamentation of the re-

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intensification stage of Typhoon Sinlaku. In 2010, we continued to analyze the Eldora radar data for Typhoon Sinlaku to study the relationship between filamentation and convection.

Our results (Kuo, Chang and Liu, 2010 submitted to Monthly Weather Review) suggest that the filamentation process suppresses deep convection in both the eyewall and the outer spiral rainband regions. Since filamentation increases with increasing TC intensity, its effect of constraining the convection will increase with an intensifying TC. This effect will be particularly strong in the outer spiral cloud band region, and will affect not only the structure of the TC but also its potential for future development.

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RESULTS

Our TCS-08 analysis of the re-intensification stage of Typhoon Sinlaku shows that the filamentation process suppresses deep convection in both the eyewall and the outer spiral rainband regions although the magnitudes are different. In the outer spiral band region 200 km from the center, the suppression is much more effective so that deep convection occur much less frequently (by a factor of 2) than shallow convection for filamentation time $\tau_{fil} < 24$ min. In addition, the rapid filamentation region is mostly collocated with the weak convective area and downward motion region in the inner side of rainband. The situation is reversed for $\tau_{fil} > 24$ min. In the eyewall cloud region where intense convective forcing is present, the effect of filamentation suppression is significantly smaller (order ~ 10%) but is still systematic and conspicuous for a faster $\tau_{fil} < 19$ min (Fig. 1).

In the TC intensifying stage, a convective free region is often observed between the eye core and the principle rainband. It is generally believed that subsidence is responsible for the suppression of the convection in this moat region. However, when an intensifying TC reaches a high intensity the subsidence is more likely confined by the inertial stability to the edge of the deep convection (Rozoff et al. 2008). The impact of subsidence thus is unlikely to be uniform throughout the clear region between the core and the rainband. On the other hand, the rapid filamentation dynamics can contribute to the organization of convection over a large area outside the eye core in an intensifying TC. In an earlier study of concentric eyewall typhoons in the North Western Pacific, we found that the rapid filamentation process tends to make an important contribution to the organization of the moat in strong typhoons (Kuo et al. 2009). In the present TCS-08 project we found that significant filamentation occurred in the inner side of the Sinlaku’s rainband in the re-intensification stage. The TCS-08 observations also indicate that the vorticity field is coupled with deep convection in the outer side of the rainband. This coupling of vorticity not only spin up the vorticity through the convergence effect in the vorticity dynamics, but also contributes to the survival of deep convection in the relative hostile strain flow environment.

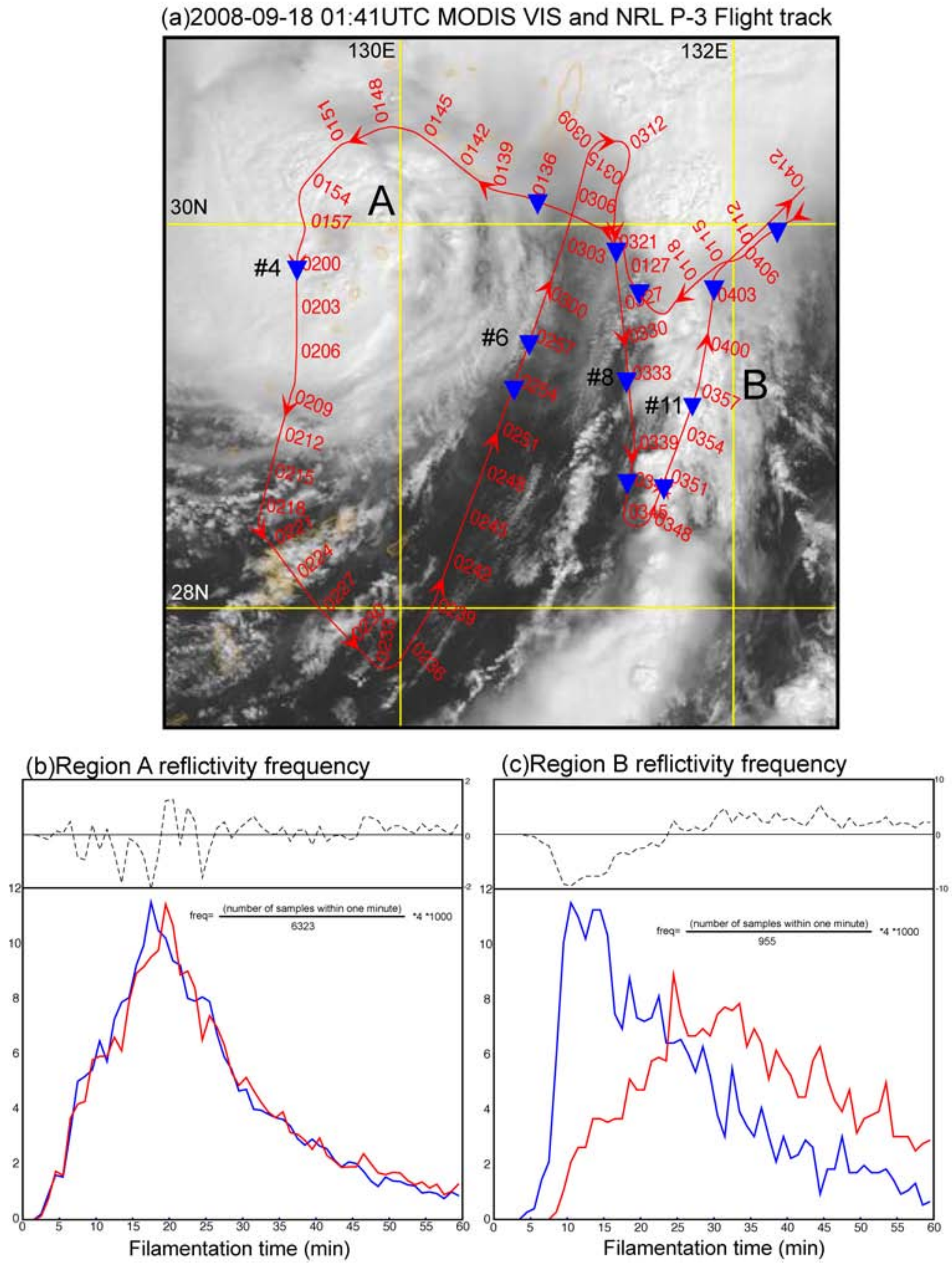

Fig 1. (a) MODIS satellite picture with the NRL P-3 flight track for the Typhoon Sinlaku. (b) The frequency distribution of filamentation time (minute) for the highest quarter (red) and lowest quarter (blue) reflectivity for region A and (c) region B. The frequency is computed as the number of samples within one minute divided by the total sample number of highest quarter and lowest quarter dBZ times 100. The dashed line at the upper panel is the difference between red line and blue line. The unit is the same as the lower panel but the scale is shown at the upper right of the frame.

IMPACT

Previously, the theoretical filamentation time for convection in a tropical cyclone can only be inferred crudely from synoptic scale data. This was the first time the filamentation growth rate is computed directly from high resolution winds that were derived from the NRL P-3 dual-Doppler radars observations in the field phase of TCS-08.

RELATED PROJECTS

TCS08 project led by Professors Russ Elsberry, Pat Harr and Michael Montgomery at NPS..

SUMMARY

The TCS-08 P3 radar data were used to compute the theoretical filamentation time from the non-divergent barotropic equation, with the results indicating that the filamentation process may indeed weaken some deep convection as predicted by certain theories.

PUBLICATION

Kuo, H.-C., C.-P. Chang, Y.-T Yang, and H.-J. Jiang, 2009: Western North Pacific typhoons with concentric eyewalls. *Mon. Wea. Rev.*, **137,** 3758-3770.

Kuo, H.-C., C.-P. Chang, and C.-H. Liu, 2010: Convection and Shear Flow in Typhoon Development and Intensification: An Observation of Typhoon Silaku during TCS-08., submitted to *Mon. Wea. Rev.*